OVERVIEW OF LAND COVER AND GEOMORPHIC INDICATORS OF BIOTIC INTEGRITY IN THE ETOWAH RIVER BASIN, GEORGIA

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REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, the University of Georgia, Athens, Georgia.

Abstract. Land cover, catchment geomorphology, stream channel geomorphology, and water quality were measured at 32 sites in the Etowah River basin north of Atlanta to identify landscape indicators of biotic integrity in Piedmont streams. Results show that multivariate models using two or three variables from these indicator categories explain 60 to 90 percent of the variation in multi-metric scores of biotic integrity for fishes and macroinvertebrates. Thus, these landscape indicators provide a suitable proxy for the biotic quality of streams, and they can be used to help manage, restore, and predict degraded and impaired stream conditions that result from urban growth and other changes in land cover.

INTRODUCTION

The main objective of this research is to define the predictive capabilities of scale-variable attributes of land cover (GIS-based) and geomorphology as risk assessment indicators of the biotic integrity of stream ecosystems. The study area is the Piedmont portion of the Etowah River basin north of Atlanta, Georgia (Figure 1), which is one of the nation's fastest growing urban areas. Various types of land cover influence water and sediment inputs (stressors) that shape stream geomorphology, which is the physical template for stream ecosystems. Landscape alteration influences these physical stressors and occurs over large areas

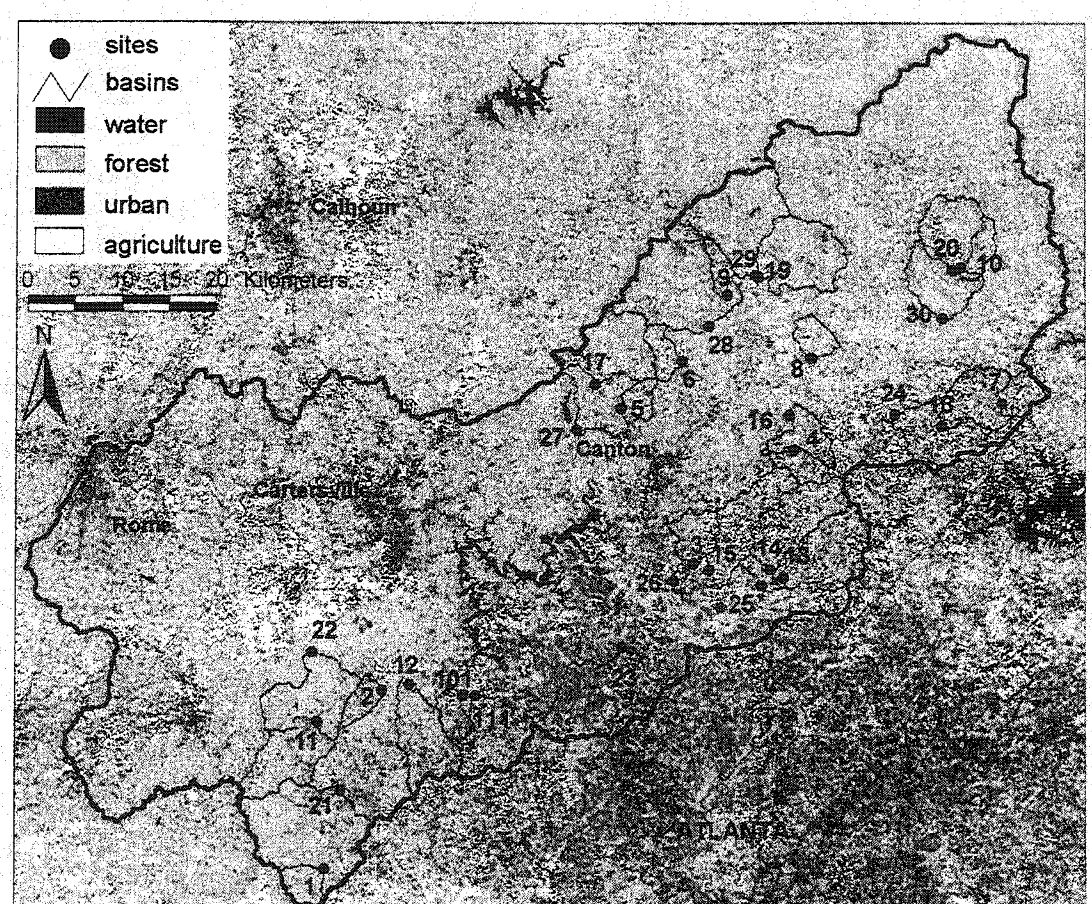

Figure 1. Land cover map (1997/1998) of the Etowah River basin showing the location of study sites and their respective catchments.

within which stream networks are nested. Previous studies have indicated that land use change results in changes in biotic integrity (Kerans and Karr, 1994; Allen et al., 1997; DeVivo et al., 1997), but such studies typically have small data sets that are spatially limited, and few studies of this sort have been done in the Southeast.

Given various aspects of landscape change, our research is investigating the following three questions. First, do physical stressors and the corresponding ecological response vary as a function of land use? Second, is this relationship consistent within watersheds of different size? Third, does antecedent land use (>30 years ago) influence the physical stressor and ecological response relationship? In order to answer these questions, our research is split into two main phases of data collection. The first phase is a comprehensive survey of geomorphic conditions and biological integrity in 32 streams and development of general predictive models ("indicators") from those physical and biotic data sets. The second phase is a detailed analysis of site-specific geomorphic conditions, stream habitat dynamics, and biotic integrity at a subset of selected sites that represent large versus small deviations from the general models produced in the first phase of analysis. This paper reports on the first phase of developing general predictive models for biotic conditions in streams of the Etowah catchment.

STUDY AREA

Thirty sites (Figure 1, #1-30) were surveyed for geomorphic conditions, fishes, and macroinvertebrates in 1999. Two more sites (#s 101 & 111) were added in 2000 to enhance our coverage of urban basins, but macroinvertebrates and water quality data have not been collected from those sites. Characteristics of these streams and catchments are presented in Table 1. The catchments range in size from 11 to 126 km^2, and were randomly selected with stratification into three target size groups of 15, 50, and 100 km^2 (+/- 25 %). The drainage area of two catchments (sites 3 and 21, Table 1) slightly exceeded the +/- 25 % limitation on size. There is no correlation between drainage area and reach slope within the size range of the 32 sites. The target size groups encompass two doublings of the 1.5 year recurrence interval flood (15 to 60 m sec^{-1}). Sites were also selected to insure a wide range of land cover characteristics indicative of different levels of human disturbance. Most of the catchments, except for heavily urbanized Noonday Creek in Cobb County (site 23), fall in the range of 40 to 95 percent forest cover, with the remainder primarily as urban and agricultural land. All

Table 1. Site and basin characteristics

Site #	Area (km^2)	Reach Slope	Water Width (m)	Water Depth (m)	Bed Texture	Urban %	Ag. %	Forest %
9	11	0.0085	5.2	0.21	cobble	16	38	43
10	12	0.0080	5.2	0.14	cobble	16	27	56
5	13	0.0031	5.4	0.15	m.gravel	9	23	67
2	14	0.0045	7.7	0.43	sand	14	30	56
6	15	0.0035	5.1	0.23	v.c. gravel	8	24	67
101	15	0.0029	4.1	0.19	granule	37	18	44
8	15	0.0058	4.9	0.17	c. gravel	6	7	87
4	16	0.0023	3.8	0.20	f. gravel	13	37	49
1	17	0.0029	5.8	0.16	granule	10	13	76
7	17	0.0020	3.9	0.25	sand	16	27	55
3	22	0.0015	4.9	0.17	granule	20	38	40
16	39	0.0052	8.1	0.18	m.gravel	11	29	60
111	48	0.0100	6.3	0.22	v.c. gravel	33	12	54
15	51	0.0015	8.8	0.12	granule	15	35	49
11	51	0.0034	9.8	0.17	m.gravel	11	21	68
12	52	0.0045	10.3	0.27	m.gravel	24	12	63
14	53	0.0025	7.7	0.17	granule	15	26	58
17	53	0.0029	6.3	0.24	m.gravel	7	15	77
18	54	0.0019	9.1	0.16	granule	19	32	48
20	54	0.0074	8.9	0.26	v.c. gravel	11	17	71
13	59	0.0015	6.3	0.22	sand	30	22	47
19	60	0.0044	8.0	0.26	m.gravel	5	8	85
29	77	0.0043	8.6	0.18	c. gravel	5	9	85
26	85	0.0013	10.5	0.15	sand	19	35	46
23	85	0.0015	6.8	0.21	granule	61	11	27
30	91	0.0033	12.9	0.50	m.gravel	10	13	76
24	96	0.0021	10.3	0.22	f. gravel	18	32	49
27	102	0.0025	12.6	0.33	f. gravel	8	16	75
28	104	0.0066	16.3	0.27	v.c. gravel	10	27	61
22	108	0.0028	15.2	0.23	m.gravel	8	18	74
25	122	0.0010	9.9	0.16	sand	23	24	52
21	126	0.0010	8.1	0.13	sand	11	11	77

of the stream channel sites are on the Piedmont, but a few of the catchments have headwaters in the Blue Ridge Mountains.

METHODS

Stream channel morphology data were collected by topographic survey with an electronic total station and visual assessment. Channel and bank sediment textures were measured by two methods, including visual point counts and mechanical sieving of grab samples. Sample reach length was scaled to approximately 20 times stream width so that 100, 150, and 200 meters were surveyed and sampled in the 15, 50, and 100 km^2 catchments, respectively. Morphometric data for basins were collected from topographic maps and digital datasets.

Land cover for each basin was measured from supervised land cover classifications derived from 1997/1998 Landsat images as part of an urbanization study of Atlanta (Lo and Yang, 2000) with pixel resolutions of 30 by 30 m. In addition, unsupervised land cover classifications have been generated from 1998 Landsat scenes. Percentages of land cover categories in each basin were measured with Arcview®.

Water chemistry was measured in-situ with a Hydrolab® and by analysis of grab samples at the University of Georgia Institute of Ecology (see Paul et al., this proceedings).

Fishes were sampled during baseflow conditions using a backpack electrofisher, seine, and dipnet in July and August 1999 for sites 1-30 and in September 2000 for sites 101 and 111. Sample reach length was scaled to approximately 40 times stream width so that 200, 300, and 400 meters were sampled in the 15, 50, and 100 km^2 catchments, respectively. Fish were classified and tablulated at the species level. An index of biotic integrity (IBI) for the Etowah basin was calculated by modifying a procedure of Karr et al. (1986). The modifications account for a lack of reference sites, regional differences in fauna, and differences among stream size groups (see Walters et al., this proceedings).

Benthic macroinvertebrates were sampled during baseflow conditions in March 6-19, 1999 from three separate elements of stream habitat, including riffles, pools, and banks within a 100 m stream segment. Three replicates of each habitat were collected. The macroinvertebratess were measured and classified to genus level using standard keys. A variety of synthetic measures were calculated (Roy, 2000), including Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness, a modified Benthic Index of Biotic Integrity (B-IBI), and modified Invertebrate Community Index (ICI, Ohio, USEPA), Hilsenhoff's Family Biotic Index (FBI) and the North Carolina Biotic Index (NCBI).

Statistical analysis of the data were carried out with standard statistical software packages, including JMP® and Sigma-Stat®. Analysis involved normality checks, bivariate regression, and multivariate regression. Data were screened to formulate preliminary multiple regression models in which the independent variables of land cover, geomorphology, visual assessment, and water quality conditions predicted biotic indices of fishes and invertebrates.

RESULTS AND CONCLUSIONS

We have developed an extensive and elaborate data set involving hundreds of variables (>300) that are still being analyzed. We find that indices of fishes and benthic invertebrates are highly predictable from physical and chemical variables, resulting in very robust predictive models (Figures 2 and 3).

In general, we found that stream geomorphic and physical habitat measures from the stream-reach scale are more significant predictors than basin-wide land cover measures. However, our results indicate that

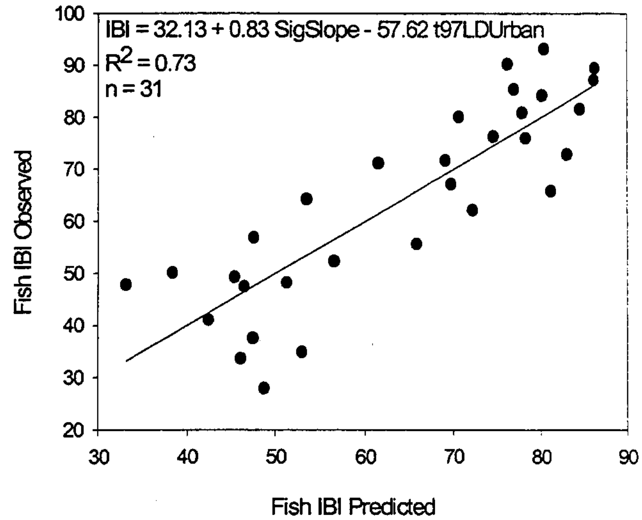

Figure 2. Residual plot of a multivariate model which predicts an index of biotic integrity (IBI) for the fishes. The predictors include a sigmoidal tranformation of reach slope (sigSLOPE), which explains 64% of the variance, and arcsin square-root transformed percent low density urban land cover, which explains 9% of the variance in the IBI. Site 2 was excluded from this model, because of a beaver dam that created unusual stream habitat.

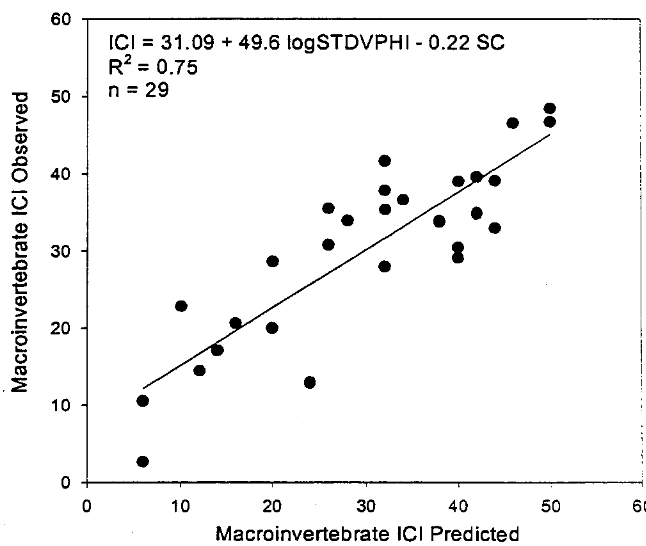

Figure 3. Residual plot of a multivariate model which predicts an index of community integrity (ICI) for the benthic macroinvertebrates. The predictors include a log transformation of the standard deviation of phi sizes for sediment (logSTDPHI), which explains 49% of the variance, and specific conductivity (SC), which explains 26% of the variance in the ICI. Site 2 was excluded from this model, because of a beaver dam.

some of the reach-specific physical characteristics, such as stream bed texture, are significantly correlated to basin-wide land cover. For example, average phi size of bed sediment and the percent fines (<2 mm) in riffles are correlated with woodland cover at <0.001 significance levels. Thus, the basin-wide "stressors" are to some extent expressed through attributes of the stream reach.

Also, we found that some of the strongest predictors of the biotic variables (i.e. stream gradient) probably are best considered as physical background parameters (i.e. stream slope), which should be used to normalize the true magnitude of human impact on the biotic system. Measures of bankfull morphology, a parameter stressed by many advocates of stream restoration (Rosgen, 1996), were not significant correlates of biotic variables. Instead, stream bed and baseflow habitat conditions generally were the most significant indicators of biotic integrity.

Another significant finding is that the 1993 Multi-Resolution Land Characterization (MRLC) land cover data (USEPA data) are inferior to single-scene classifications of more recent Landsat images insofar as correlations to 1999 physical and biotic data are concerned. Initially, based on the 1993 MRLC data, we concluded that land cover was not a very significant variable for predicting biotic conditions, because the 1993 variables failed significance tests for correlation at the 0.05 level. However, we later obtained data from 1997-1998 Landsat images that were closer in time to our sampling and probably are classified more accurately than the 1993 MRLC data set. As a result, many of the correlations between land cover and biotic conditions improved immensely and became highly significant ($p<0.01$)(Figure 2). In fact, there was as much as a 10-fold increase in the bivariate Pearson correlation coefficients (R-values) resulting from correlations between fish IBIs and the 1997/1998 land cover data when compared to the 1993 MRLC land cover data. We are currently trying to derive the best multivariate models using land cover data from 1997 and 1998.

Our future goals are to formulate the best multivariate models from several different standpoints related to different classes of data and different levels of cost/benefit ratios of indicator variable measurement. We are interested in the best model from the perspective of labor efficiency, such as models from remotely sensed imagery, limited field work, and visual assessment protocols. In contrast, we are also interested in the best model in terms of overall predictive capabilities and understanding mechanistic relationships, regardless of labor costs. Also, we are working toward finding the best models to explain the relationships between basin-wide measures and stream-reach measures in order to resolve some of the indirect linkages between landscape changes in the basin and attributes of the stream reach.

Our results indicate a high degree of reliability in estimating the biotic conditions of Piedmont streams from physical measurements of the landscape and water quality parameters from the stream site. General models from study in the Etowah basin should be transferable to other Piedmont streams. We anticipate that this research will provide useful tools for managing, restoring, and predicting impairment and degradation of streams across the Piedmont from Alabama to New Jersey that result from urban growth and other land cover changes.

ACKNOWLEDGMENTS

This study was funded by grants from the U.S. Environmental Protection Agency (EPA# R826597-01-0) and the University of Georgia Research Foundation, Inc. Special thanks to A. Bearden, R. Cifaldi, and R. Malhotra for technical assistance.

LITERATURE CITED

Allen, J. D., D. L. Erickson, and J. Fay, 1997. The influence of catchment land use on stream integrity across multiple spatial scales. Freshwater Biology 37:149-161.

DeVivo, J. C., C. A. Couch,, and B. J. Freeman, 1997. Use of a preliminary index of biotic integrity in urban streams around Atlanta. *In* (K. Hatcher, ed.) 1997 Proceedings of the Georgia Water Resources Conference, The University of Georgia Institute of Ecology, Athens.

Karr, J. R., K. D. Fausch, P. L. Angemeir, P. R. Yount, and I. J. Schlosser, 1986. Assessing biological integrity in running waters: a methoc and its rational. Illinois Nat. Hist. Survey Special Pub. 5, Champaign.

Kerans, B. L., and J. R. Karr, 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. Ecological Applications 4:768-785.

Lo, C. P. and X. Yang: "Mapping the dynamics of land use and land cover change in the Atlanta Metropolitan Area using time sequential Landsat images", ASPRS 2000 Proceedings (in CD form), Annual Meeting held in Washington DC, May 22-26, 2000, American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland

Rosgen, D. L., 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Roy, A. H., 2000. Macroinertebrate Responses to Watershed Urbanization in the Etowah Basin, Georgia. Unpublished Masters Thesis, The University of Georgia, Athens.